

The Littoral Sedimentation and Optics Model (LSOM)

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10 May 2002

Motivation

The Navy needs a capability to predict nearshore bottom properties and water column optical characteristics at forecast intervals up to 72 hours.

OUTLINE

- Overview of LSOM
- Resuspension
- Active Layer
- Transport Algorithms
- Mass (bed) Conservation
- Bed Definitions

LSOM: OVERVIEW

- 2D finite-difference computation grid
- 1D BBLM computes profiles
- Mass-conservation equations for spectrum of silt/sand sizes
- Mud algorithms
- Bed load, advection, and diffusion terms
- Spectral and total erosion and deposition
- Algorithms for optical scattering and diver visibility

LSOM: FLOW

INPUT: 2D
current,
wave, and
sediment
parameter
fields

2D GRID
LOOP

BBLM

u_* , C_0 , h_A , etc.

SIZE
LOOP

Sediment profiles

Resuspension depth
 H_R

Recompute
profiles

$H_R > h_A$

YES

Reduce
reference
concentration.

Bed, suspended,
and diffusion fluxes

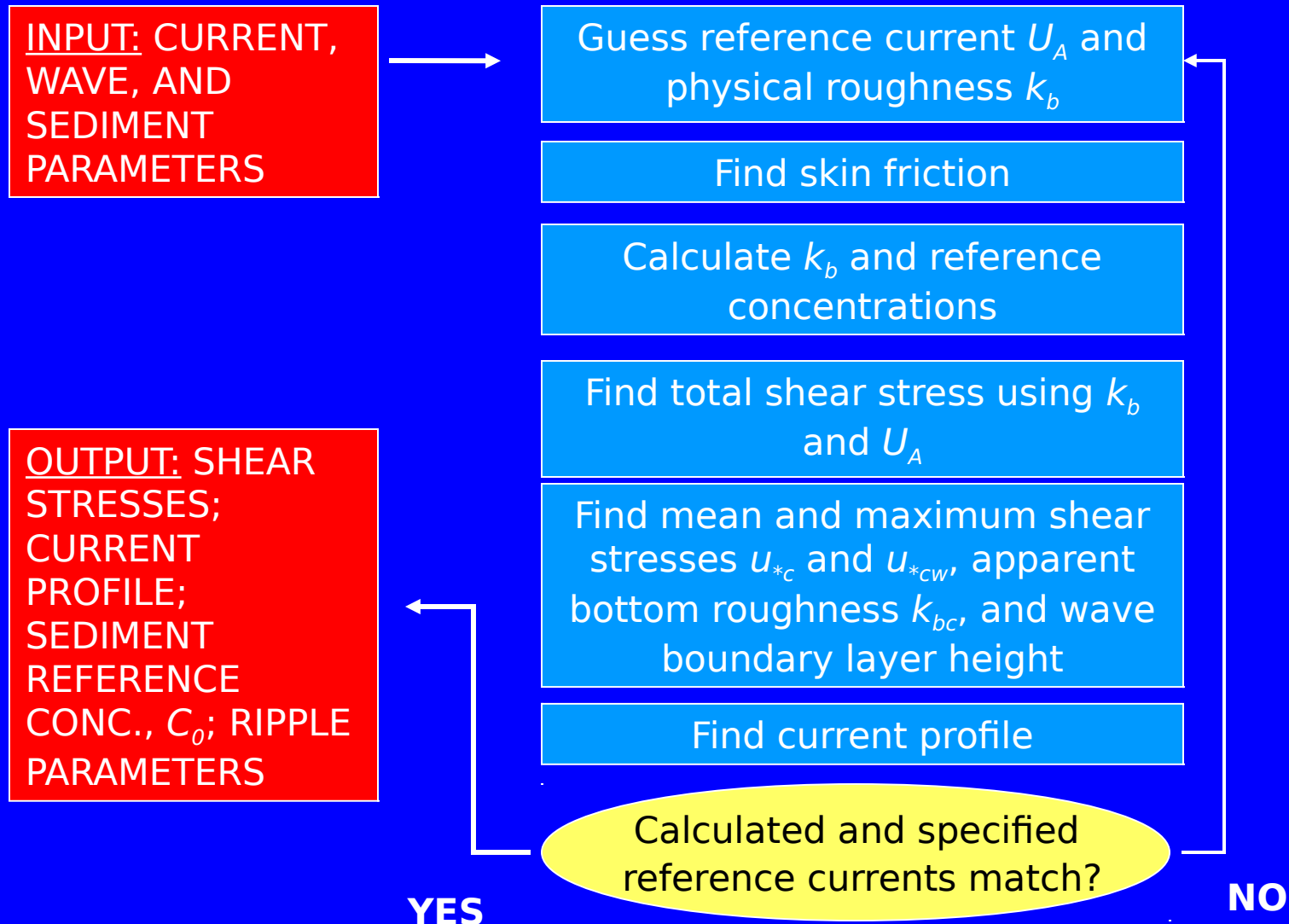
Solve mass
conservation
equation

Bed parameters

Integrated bed parameters

OUTPUT: 2D
beds;
sediment
profiles;
scattering
coefficients;
diver
visibility;

BBLM: FLOW



SILT/SAND REFERENCE CONCENTRATION

- Instantaneous reference concentration $c_n(z_0)$
- Average over wave period to find mean concentration $c_{mn}(z_0)$

Diagram illustrating the equation for mean concentration $c_{mn}(z_0)$ as a function of bed concentration c_{bm} and normalized excess skin friction $\gamma_0 S'_n$.

The equation is:

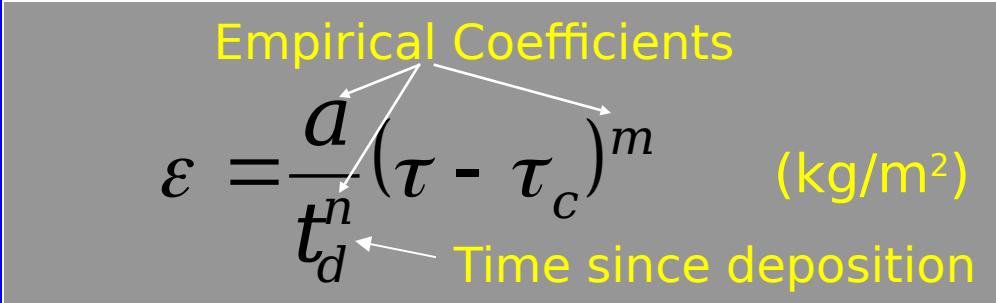
$$c_{mn}(z_0) = c_{bm} \frac{\gamma_0 S'_n}{1 + \gamma_0 S'_n}$$

Labels and arrows pointing to the equation components:

- bed concentration c_{bm} (points to c_{bm})
- normalized excess skin friction $\gamma_0 S'_n$ (points to $\gamma_0 S'_n$)
- instantaneous resuspension coefficient γ_0 (points to γ_0)
- size class n (points to n)

COHESIVE SEDIMENT DYNAMICS: ENTRAINMENT

- Resuspended concentration*:



The diagram shows the equation $\varepsilon = \frac{a}{t_d^n} (\tau - \tau_c)^m$ with units (kg/m²). Annotations include: 'Empirical Coefficients' with arrows pointing to a and m ; and 'Time since deposition' with an arrow pointing to t_d .

$$\varepsilon = \frac{a}{t_d^n} (\tau - \tau_c)^m \quad (\text{kg/m}^2)$$

- Need to examine the empirical coefficients a , n , and m using mineralogical and chemical data.
- Replace power-law formulation with physical models for clay diagenesis and entrainment.

SUSPENDED SEDIMENT PROFILES

Mean concentration within wave boundary layer:

$$C_{mn}(z) = C_{mn}(z_0) \left[\frac{z}{z_0} \right]^{-\frac{\gamma w_{fn}}{\kappa u_{*cw}}}$$

Dimensionless fall velocity

Diffusivity parameter

Mean concentration above wave boundary layer:

$$C_{mn}(z) = C_{mn}(\delta_w) \left[\frac{z}{\delta_w} \right]^{-\frac{\gamma w_{fn}}{\kappa u_{*c}}}$$

Wave boundary layer height

ACTIVE LAYER CALCULATION

- The BBLM computes a resuspension depth for each size class.
- depth is limited by:
 - near-bed transport:
 - ripple height:

$$h_{Tm} = 42(s + 1/2)d\psi_c \sqrt{\frac{\psi'_m}{\psi_c}} - 0.7^2$$

Relative density s
 Critical Shields parameter ψ_c
 diameter d
 Max Shields parameter ψ'_m

Break-off range

$$\eta = 0.48s_*^{0.8}A_b \left(\frac{\psi_m}{\psi_c} \right)^{-1.5}$$

Sediment parameter A_b

Equilibrium range

$$\eta = 0.22A_b \left(\frac{\psi_m}{\psi_c} \right)^{-0.16}$$

Wave orbital diameter A_b

COUPLING BBLM TO TRANSPORT MODEL

- The BBLM is applied independently at each grid point on a 2D horizontal grid.
- The corrected suspended sediment profiles are coupled to 2D transport equations for all size classes.
- The active layer is found from near-bed transport and ripple height.

MASS-CONSERVATION EQUATIONS

- The suspended sediment ADVECTION flux in x direction for size n :

$$S_n = \Delta_y \int_{z_0}^{z_1} u(z) c_{mn}(z) dz$$

BED LOAD

- Modified Bagnold formulation:

$$i_{bn} = c_{bn} \frac{\log\left(\frac{z_b}{k_b}\right)}{\kappa \tan \alpha} (u_{*cw} - u_{*n})(\tau_{*cw} - \tau_n)$$

Thrust height on grain $\rightarrow z_b$
 Critical shear velocity $\rightarrow u_{*cw}$
 Critical shear stress $\rightarrow \tau_{*cw}$
 Bed concentration $\rightarrow c_{bn}$
 Dynamic friction coefficient $\rightarrow \tan \alpha$

SEDIMENT DIFFUSION EQUATIONS

- The suspended sediment DIFFUSION flux in x direction for size n :

$$D_n = \Delta_y A_H \int_{z_0}^{z_1} c_{mn}(z) dz$$

Horizontal diffusivity

- A_H is Smagorinsky formulation

MASS-CONSERVATION EQUATIONS

- Total derivative in x direction for size n :

$$\rho_s (1 - \varphi) \frac{\partial}{\partial t} (\Delta_y z_n) + \frac{1}{G} \frac{\partial}{\partial x} (\Delta_y i_{bn}) + \frac{\partial S_n}{\partial x} + \frac{\partial D_n}{\partial x} = 0$$

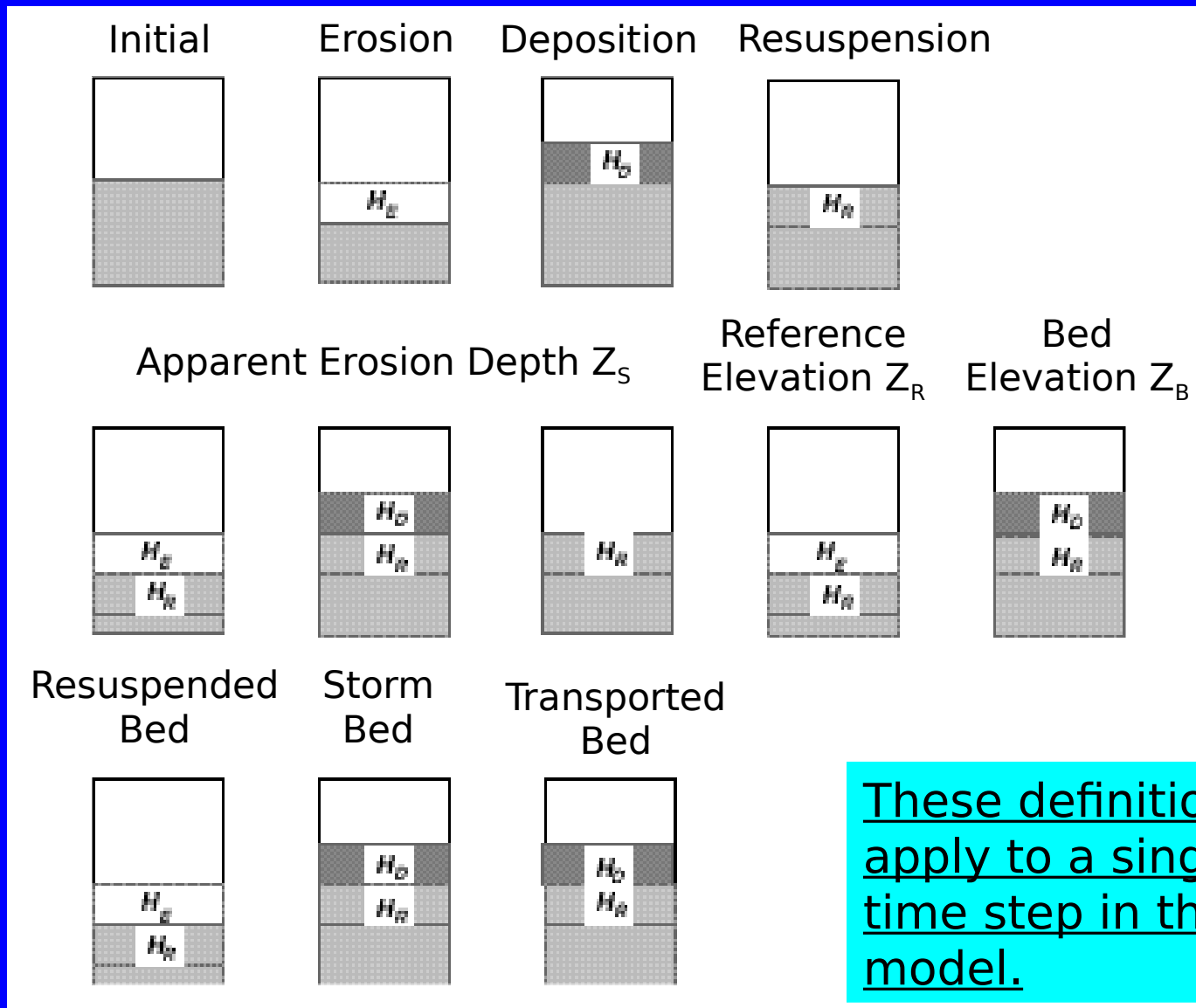
Diagram illustrating the mass conservation equation for size n , with terms labeled as follows:

- ρ_s : Sediment density
- $(1 - \varphi)$: Bed porosity
- $\frac{\partial}{\partial t}$: Time derivative
- $\Delta_y z_n$: Elevation change (Y dimension)
- $\frac{1}{G}$: Gravitational constant
- $\frac{\partial}{\partial x}$: X direction derivative
- $\Delta_y i_{bn}$: Bedload transport rate
- S_n : Suspended sediment advection flux
- D_n : Suspended sediment diffusion flux

BED DEFINITIONS

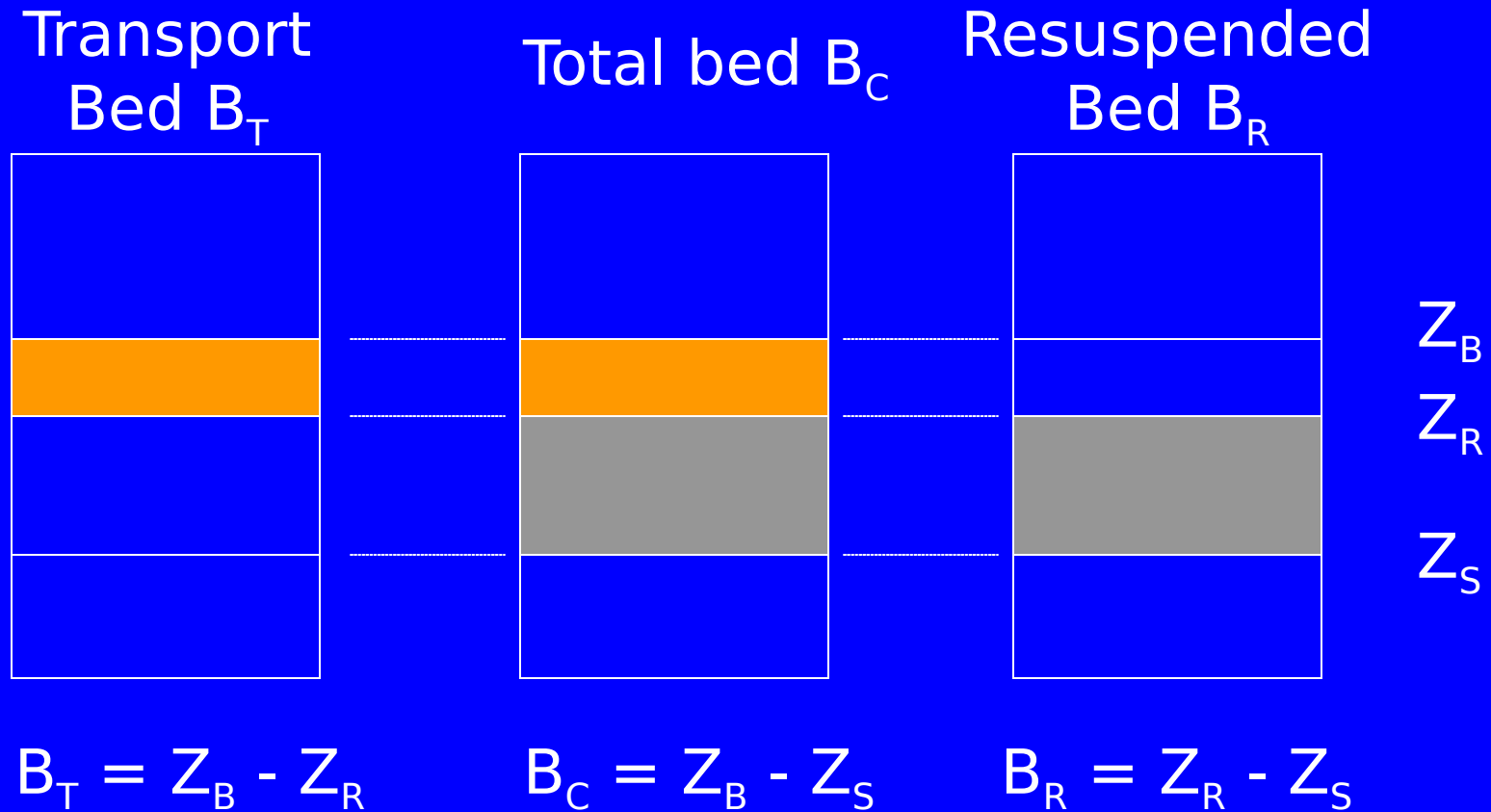
- Storm Bed: thickness of reworked sediment
- Resuspension Bed: equivalent thickness of resuspended sediment
- Transported Bed: sediment deposited after transport by steady currents from another location

INSTANTANEOUS TOTAL BEDS



These definitions apply to a single time step in the model.

CUMULATIVE TOTAL BEDS



These beds are present after last model integration.

CONCLUSIONS

- LSOM is a modular, scalable, multipurpose model for Navy needs.
- It is being enhanced with cohesive sediment algorithms.
- A PC-based windows version is currently under development.